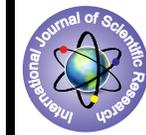


Factors Affecting Ground Water Depletion of Water Stressed Bhatar Block of Burdwan District, West Bengal



GEOGRAPHY

KEYWORDS : Ground Water Depletion, Variability of Rainfall, Water Stress.

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ABSTRACT

The present work critically explains the responsible factors related to ground water resource depletion of Bhatar Block. The study area is agro-rich area of Burdwan District and during last few year drastic change of cropping pattern is being noticed. The study shows that the average depth of the ground water table from the surface increased 166% during 1985 to 2014. The strongest association is found in the case of relationship between expansion of Rabi and Boro paddy cropped area with ground water depth. Thus the block is facing a severe crisis in its ground water resource condition and the crisis stems generally from LULC change, especially extension of Rabi cropped and Boro paddy cultivated area. In the concluding part, an appropriate plan for water resource conservation, encouragement for wheat cultivation instead of excess boro paddy cultivation, conjunctive use of water are recommended.

1. Introduction

Surface water resource is the main usable water supply to meet up human need worldwide, but the significance of underground water is growing as supply of surface water happens to less dependable and predictable (Kundzewicz and Döll, 2009). Depleting ground water levels is the leading warning to rural society and food protection in the world. Globally ground water is the important source of fresh water supply. To evaluate the future water availability, is very necessary to understand the gap between ground water used and volume of water available in the present time (Alexander et al. 2015). World water resources are under stress¹ to meet future expectations due to rapid population growth, Land use Land cover (LULC) change and climate change (Kundzewicz et al., 2008, Famiglietti, 2014). There are three chief approaches to enumerate water stress (Rijsberman, 2006). The important one is the evaluation of the socio-economic and physical factors that influence water stress [Sullivan et al., 2003]. Diouf (2007) reported that by 2025, 2/3 of the world population will be living under water-stressed conditions. Due to excess withdrawals, and poor management of water resource the depth of ground water level has lowered, soil quality has deteriorated and reduced water quality Worldwide (Rosegrant, 2002).

India's water crisis is predominantly a manmade problem. Brooks (2007) reported, extremely poor management, unclear laws, Government corruption and water waste have caused this water supply crisis. India's per capita water availability will reduce sharply to 1,340 m³ by 2025 (Frost and Sullivan, 2011), while in 2010, per capita water availability was 5200 m³ in 1951². This picture highlights an ominous sign of the rising water shortage in the country.

Evidently, West Bengal is not free from the problems of water scarcity. According to estimation of State Irrigation Department, requirement of water for agricultural sector would increase from 7.71Mham in 2011 to 10.98 Mham in the years 2025 and that is more than obtainable water resource for utilisation by all other sectors³.

During last few years complete reshape in agricultural system is being observed in Bhatar Block (Biswas, 2009). The total population of the area has increased above 70% from 1971-2011. The concept of population growth and water resource depletion are closely linked, because the demand for water resources is escalating constantly with population growth (Bartlett 1999). The average depth of the ground water table from the surface increased from 7.4 meter (1985) to over 19.7 meter (2014). Further intensification

of the situation may put the sustainability of the region's economy and environment in danger.

The present paper focuses and explains in detail the possible factors of ground water resource depletion.

2. Study Area

Bhatar Block, the study area is located in the Burdwan district of West Bengal. The latitudinal extension of this Block is from 23° 22'N to 23° 30' N and longitudinal extension is 87° 44'E to 88° 03' 30"E (Fig.1). Range of elevation of the area is 20m to 60m and regional slope is from west to east.

In the area, there are no any notable rivers but some right bank tributaries of Ajoy are present here such as Khari Nadi, Kandar, Kunur, Tumni, Brahmani, and Bagdob Nadi (Fig. 2).

Figure 1: Satellite image of Bhatar Block

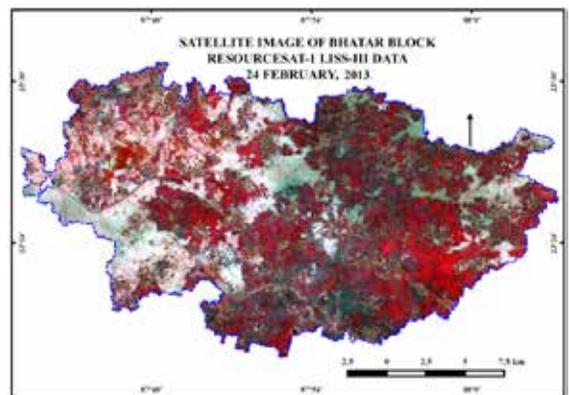
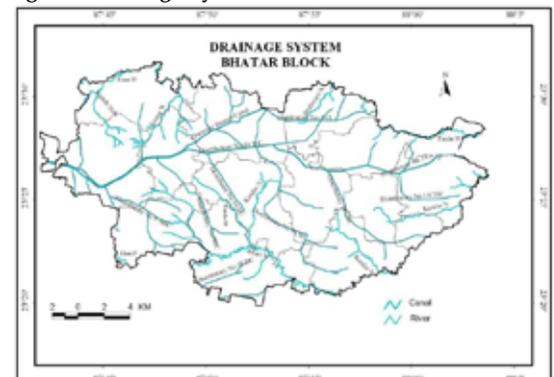


Figure2: Drainage System of Bhatar Block



Source: Satellite Image (IRS, P6 LISS-III data, 2013 and Survey of India (SOI) Topographical map 1972

3. Data base and Methodology

Different agricultural data have been collected from Agriculture Development Office (A.D.O), Bhatar and Agricultural Development Office, Burdwan Sadar. Data of ground water resources of the Bhatar Block have been collected from the State Water Investigation Directorates (SWID), Burdwan and Kolkata Sech Bhawan, West Bengal. Rainfall data is collected from Bhatar agricultural farm. Satellite Images (IRS-P6, LISS-3 data, 2013) have been downloaded from the site of Indian Space Research Organisation (ISRO) and four sheets of Topographical maps were collected from SOI, Kolkata.

Variability of annual rainfall is computed with the help of following formula;

$$\text{Coefficient of Variability (CV)} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$$

To understand the strongest factor affecting ground water depletion, a correlation matrix has been calculated with the help of SPSS software.

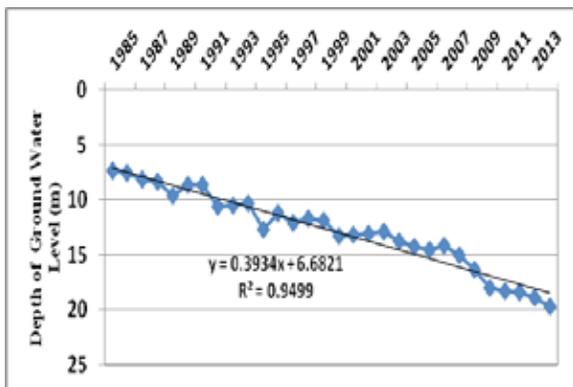
4. Objectives

- a) To explore the existing factors responsible for water resource depletion.
- b) To estimate of water requirement for agriculture and domestic uses.
- c) To find out the contribution of climatic factors in water resource depletion and
- d) To find out the strongest factor of water resource depletion of the concerned area.

5. Result and Discussion

Ground Water Depletion: Figure-3 shows that in 1985 the average depth of ground water level was 7.4m and in 2014 it touches the level of 20m. During last 29 years average water level of the Bhatar Block exhausted above 166 %. The rate of degradation of water level is 0.39 (Fig. 3) and R² value is 0.9499.

Figure 3: Temporal Change of Ground Water Level



5.1. Causes behind the Change of Water Resources

All the possible reasons for water resource depletion of Bhatar Block are;

- a) Climatic Factor (Rainfall)
- b) Increasing demand of water resource in the domestic sector
- c) Land use land covers change

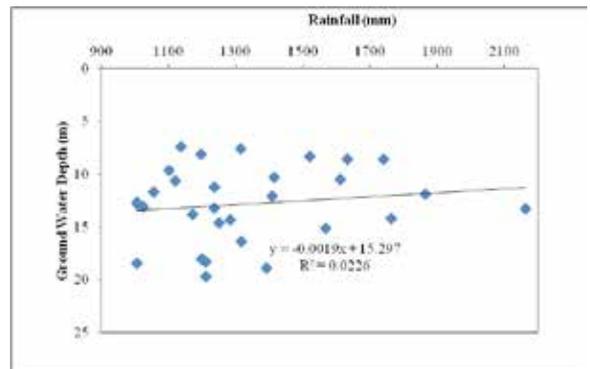
All these possible factors of water resource depletion of the block need to be examined and explained in detail for the sake of the study.

Rainfall

Under this section the investigation of the impact of rainfall on ground water level depletion of Bhatar Block has been done.

Figure 4 signifies weekly negative relationship between rainfall and ground water level as conceptualized. This is a natural phenomenon that the amount of ground water recharge increases with increasing rainfall and thus ground water level depth from the surface decreases.

Figure 4: Relationship between Rainfall and Ground Water Depth of Bhatar Block



Variability of Rainfall

Variability of annual rainfall is computed here.

$$\text{Coefficient of Variability of Rainfall (CV)} = \frac{284.2469}{1339.33} = 21\%$$

The coefficient of variation of rainfall value is only 21 %. So it can be said that the region lies in the zone of low coefficient of variation which indicates the region lies in normal rainfall zone. Therefore it can be said that the other factors of ground water level fluctuation are operating more strongly than the rainfall.

Increasing Demand of Water Resource in Domestic Sector

About 90% of domestic water in the Bhatar Block is used from ground water. The density of population has increased on average for the block from 372 persons/ km² in 1971 to 639 persons/km² in 2011.

The per capita use of water for domestic purposes in rural India is 40 liters per day⁴ (Government of India) on average. So according to this measure the mode of change of domestic consumption of water of the block is given table 1.

Table 1: Changes of Domestic Consumption of Water resource of Bhatar Block

Administrative unit	1971		2011	
	Population	Consumption Per day in liters Per annum in m ³	Population	Consumption Per day in liters Per annum in m ³
Bhatar Block	153989	6159560 2248239	263064	10522560 3840734.4

Source: Census of India 1971, and 2011, Water data calculated by author based on report of Government of India.

Table 1 shows that the consumption of water for domestic purposes in Bhatar Block increased by 70.8 percent in the

years between 1971 and 2011. Though the domestic water use is increasing with increasing population the present study tries to find out other important factor of ground water depletion.

LULC Change and Water Resource Depletion

Due to unavailability of canal water and rainfall in winter season, farmers of the region have installed huge number of pump sets and are withdrawing ground water for cultivation of winter crops.

It has been observed through field surveys that Boro paddy has replaced the oilseeds and pulses cultivation of this block and it is a very water intensive crop.

Installation of huge number of submersible pump is the main cause of rapid expansion of Boro paddy and winter vegetables cultivated land. Agro-irrigation department Burdwan sub-division reported that 12192 m³ water is needed for per hectare 'Boro' paddy cultivation. A calculation of amount of ground water withdrawal for 'Boro' cultivation in different period is done (Table 2).

It is cleared from the Table: 2 that in 1985-86, the ground water withdrawal was 9753.60 ham for 'Boro' paddy cultivation. It is found that highest ground water withdrawal is recorded in 1998-99 and the year 2009-10. It is found that the ground water withdrawal shows a significant increase of 155 % over last 29 years. So the number of pump sets has increased considerably with the increasing of the cultivated land under 'Boro' paddy. The number of pump sets has increased about 450 % from 1985 to 2014 whereas the amount of land under 'Boro' cultivation has increased 150 percent in the corresponding.

Table 2: Change of Boro Paddy Cultivated land and Ground Water Withdrawal for Boro Paddy Cultivation, 1985-2014

Year	Boro Paddy Cultivated Land (ha)	Volume of ground Water Withdrawal for Boro Paddy Cultivation(ham)
1985-86	8000	9753.6
1986-87	7800	9509.76
1987-88	7800	9509.76
1988-89	8000	9753.6
1993-94	12000	14630.4
1997-98	18000	21945.6
1998-99	24000	29260.8
1999-00	18500	22555.2
2000-01	18000	21945.6
2001-02	17575	21427.44
2002-03	21500	26212.8
2003-04	19000	23164.8
2004-05	17500	21336
2006-07	17250	21031.2
2007-08	23750	28956
2008-09	22000	26822.4
2009-10	24000	29260.8

2010-11	15450	18836.6
2011-12	16700	20360.64
2012-13	20696	25232.56
2013-14	20030	24420.58

Source: ADO, Bhatar (2015) and volume of ground water calculated by researcher based on the information of Agro-irrigation Department, Burdwan sub-division (2014).

5.2. Correlation Matrix

Pearson's Coefficient of Correlation is used in this study. While summarizing correlation coefficient of 'Rabi' cropped area, Amon paddy cultivated area, rainfall and ground water depth the use of correlation matrix is significant.

The relationship of rainfall and agricultural land use change with ground water depletion is expressed through the calculation of correlation coefficient. The calculation of correlation matrix is done with the variables of average depth of ground water level, annual mean rainfall, 'Amon' cultivated land and Rabi plus 'Boro' cropped area for the time period 1985 to 2014(Table 3).

As the main issue under discussion is ground water resource depletion, so the analysis of different variables with ground water resource depletion is done.

Table 4 shows the relationship between annual mean rainfall and ground water depth from the surface is slightly low negative correlation (r= -0.23). It means that as rainfall increases, the depth of ground water decreases.

Correlation coefficient value of 'Amon' cropped area and ground water depth is -0.360 which indicates weak negative correlation between the two which indicates that it makes no impact on changing ground water depth.

Another analysis of correlation between Rabi and 'Boro' cropped area with the level of ground water depth shows significant positive trend. The value of r= 0.761. It implies that as Rabi and 'Boro' cropped area increases, ground water depth also increases. In this case the value of significance (2 tailed tests) is 0.000 (Table 4 & 5) which is less than our present level of significance (0.01 level, 2 tailed test), indicating the relationship between these two variables are statistically significant.

Table 3: Rabi and Boro Paddy Area, Amon Paddy Area, Annual Rainfall and Ground Water Depth of Bhatar Block, 1985-2014

Year	Rabi and Boro Paddy area (ha)	Amon Paddy area(ha)	Annual Rainfall (mm)	Average Depth of Ground Water (m)
1985	12633	30400	1137.9	7.4
1986	12397	29792	1315.3	7.6
1987	11808	29408	1198	8.1
1988	12102	30457	1520	8.3
1990	12194	30257	1740	8.6
1993	15568	29000	1611.4	10.5
1997	23425	30400	1409.1	12.1
1999	22974	28000	1865.4	11.9
2000	21861	28000	2163.38	13.3
2001	21956	27000	1237.7	13.2
2002	23705	28400	1025.7	13.1

2004	25375	26255	1172.8	13.8
2005	22736	25980	1283.6	14.3
2006	22438	27050	1252	14.6
2007	26950	26850	1763.8	14.2
2008	27631	28850	1567.9	15.1
2009	28690	28750	1318	16.4
2010	29337	28685	1199.5	18
2011	20675	28500	1212.2	18.3
2012	24367	28800	1005.4	18.4
2013	23415	29100	1393.13	18.9
2014	20502	29000	1212	19.7

Source: ADO, Bhatar, Agriculture farm of Bhatar Block and SWID Burdwan, 2015

The correlation matrix for the data set is presented below:

Table 4: Composite Correlation Matrix

Correlations					
		Rabi & Boro Paddy Cropped Area(Hect.)	Amon Crpped Area (Hect.)	Annual Rainfall (mm)	Ground Water Depth (m)
Rabi & Boro Paddy Cropped Area(Hect.)	Pearson Correlation Sig. (2-tailed)	1.000	-.554**	-.046	.761**
	N	22	22	22	22
Amon Crpped Area (Hect.)	Pearson Correlation Sig. (2-tailed)	-.554**	1.000	.006	-.383
	N	22	22	22	22
Annual Rainfall (mm)	Pearson Correlation Sig. (2-tailed)	-.046	.006	1.000	-.230
	N	22	22	22	22
Ground Water Depth (m)	Pearson Correlation Sig. (2-tailed)	.761**	-.383	-.230	1.000
	N	22	22	22	22

** . Correlation is significant at the 0.01 level (2-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Rabi and Boro Paddy Cultivated Land (Hect.)	21033.59	5703.8902	22
Amon Paddy Cropped Area(Hect)	28587.91	1320.2680	22
Annual Rainfall (mm)	1391.1005	290.8444	22
Average Depth of Ground Water (m)	13.4455	3.8685	22

Table 5: Descriptive Statistics

So it can be concluded that the expansion of Rabi and 'Boro' cropped area is the strongest factor of ground water depletion.

There are many causes of water resource depletion in the block, the crisis stems generally from LULC change, especially extension of Rabi cropped and Boro paddy cultivated area.

6. Conclusion

Reckless pumping of ground water for irrigation is a prominent character of the agro rich Bhatar Block. The uncontrolled rate of water withdrawal from aquifers is alarmingly faster than the natural rate of recharge, causing sharp fall of water tables.

If this situation continues unabated for a few decades, it is apprehended that one of the main factors limiting future food production will be water. It is absolutely necessary to make meticulous plan to meet the growing need for water resource in the region.

The shift of cultivation practice from 'Boro' to 'Amon' is suggested for sustaining the ecological stability of the re-

gion. Huge water needy winter and summer crop replacement may be a measure for saving of ground water. In Bhatar Block the amount under wheat is much less than that the amount of the 'Boro' cultivated area. My recommendation is the replacement of 'Boro' cultivation by wheat cultivation, because it needs less water than 'Boro' paddy and this will go a long way in saving ground water. It is also observed that the area under mustard and the different type of pulses has been reduced significantly due to the dominance of 'Boro' paddy cultivation but actually these crops need much less water than that of the 'Boro' paddy. So it requires the change in the Rabi cropping pattern and there is imperative need to sensitize the people about the crisis which can be mitigated by cultivating wheat, pulses, mustered etc in place of 'Boro' paddy.

7. Acknowledgement

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